

DETECTING LOW-CONTRAST FEATURES IN THE COSMIC RAY ALBEDO PROTON MAP OF THE MOON. J. K. Wilson¹, N. Schwadron¹, H. E. Spence¹, M. J. Golightly¹, A. W. Case^{2,7}, S. Smith¹, J. B. Blake³, J. Kasper^{2,7}, M. D. Looper³, J. E. Mazur³, L. W. Townsend⁴, C. Zeitlin⁵, T. J. Stubbs⁶, ¹Space Science Center, University of New Hampshire, Durham, NH, (jody.wilson@unh.edu), ²High Energy Astrophysics Division, Harvard CFA, Cambridge, MA, ³The Aerospace Corporation, Los Angeles, CA, ⁴Department of Nuclear Engineering, University of Tennessee, Knoxville, TN, ⁵Southwest Research Institute, Boulder, CO, ⁶NASA Goddard Space Flight Center, Greenbelt, MD, ⁷NASA Lunar Science Institute.

Introduction: High energy cosmic rays constantly bombard the lunar regolith, producing (via nuclear evaporation[1]) secondary “albedo” or “splash” particles like protons and neutrons, some of which escape back to space. Lunar Prospector and the Lunar Reconnaissance Orbiter (LRO), have shown that the energy distribution of albedo neutrons is modulated by the elemental composition of the lunar regolith[2-5], and by ice deposits[6] in permanently shadowed polar craters. Here we investigate an analogous phenomenon with high energy (~100 MeV) lunar albedo *protons*.

CRaTER Instrument: LRO has been observing the surface and environment of the Moon since June of 2009. The CRaTER instrument (Cosmic Ray Telescope for the Effects of Radiation) on LRO is designed to characterize the lunar radiation environment and its effects on simulated human tissue. CRaTER's multiple solid-state detectors can discriminate the different elements in the galactic cosmic ray (GCR) population above ~10 MeV/nucleon, and can also distinguish between primary GCR protons arriving from deep space and albedo particles propagating up from the lunar surface.

Results so far: We use albedo protons with energies between 60 MeV and 150 MeV to construct a cosmic ray albedo proton map of the Moon. The yield of albedo protons is proportional to the rate of lunar proton detections divided by the rate of incoming GCR proton detections. The map accounts for time variation in the albedo particles driven by time variations in the primary GCR population, thus revealing any true spatial variation of the albedo proton yield.

Our current map is a significant improvement over the proof-of-concept map of Wilson et al.[7]. In addition to using more numerous minimum ionizing GCR protons for normalization, we filter out all solar particle enhancement periods, correct for certain subtle observational biases, and make use of all six of CRaTER's detectors to reduce contamination from spurious non-proton events in the data stream.

The average yield of albedo protons from the maria is $0.8\% \pm 0.4\%$ higher than the yield from the highlands. In addition there appear to be localized peaks in the albedo proton yield, with one peak possibly co-located with peaks in trace elemental abundances as

measured by the Lunar Prospector Gamma Ray Spectrometer.

Next Steps: More data may reveal subtler proton yield variations correlated with latitude, time of day, or the locations of permanently shadowed craters, due to the presence of water frost. Given that the most obvious features in the map have a proton yield only 2σ above average, the search for more subtle regions of enhancement or reduction in proton yield will require precise corrections for small but systematic effects of time and spacecraft altitude on the apparent proton yield.

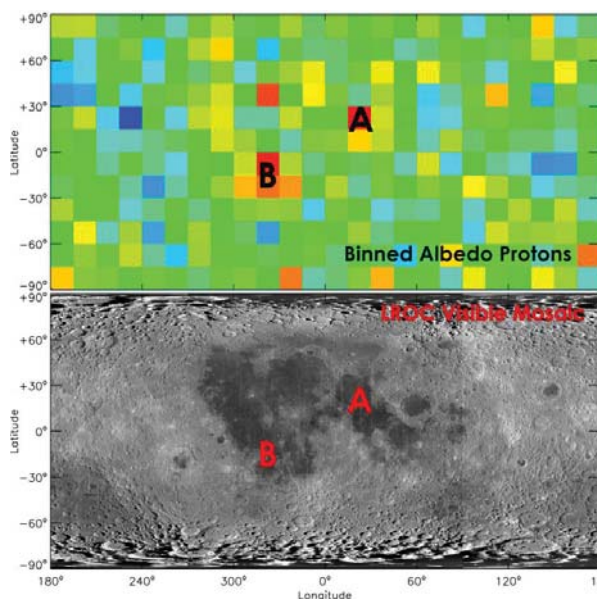


Figure 1. Top: Color-coded lunar albedo proton map, with two high-yielding mare regions labeled “A” and “B”. Bottom: Clementine white-light mosaic of lunar surface.

References: [1] Bethe (1937) *Rev. Mod. Phys.*, 9, 69. [2] Feldman W. C. et al. (1998) *Science*, 281, 1496-1500. [3] Gasnault, O. et al. (2001) *GRL*, 28, 3797-3800. [4] Maurice, S. et al. (2004) *JGR*, 109, E07S04. [5] Mitrofanov I. G. et al. (2010) *Science*, 330, 483-486. [6] Feldman W. C. et al. (1997) *JGR*, 102, 25565-25574. [7] Wilson, J. K. et al. (2012) *JGR*, 117, E00H23.